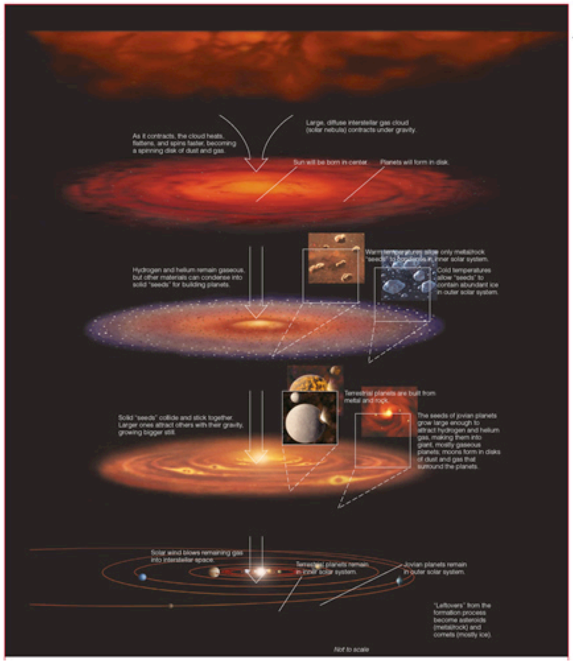
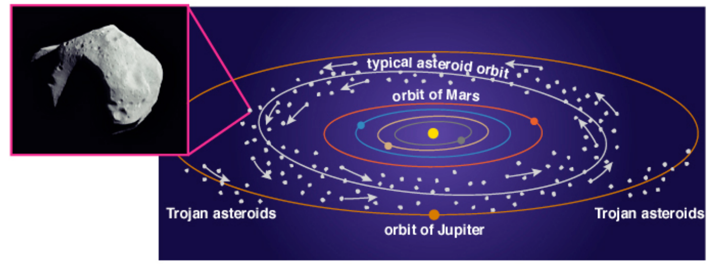
# Nebular Theory: Summary

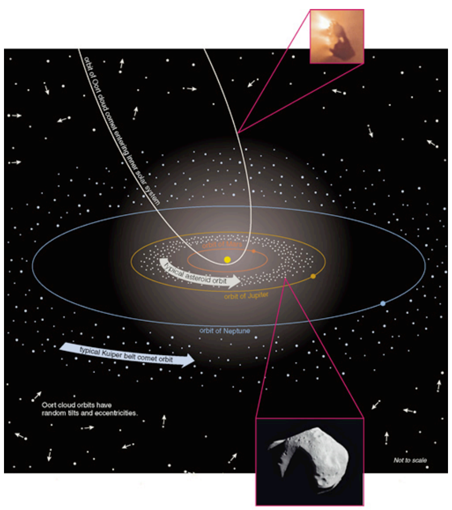


# Origin of the Asteroids

- The Solar wind cleared the leftover gas, but not the leftover planetesimals.
- Those leftover rocky planetesimals which did not accrete onto a planet are the present-day **asteroids**.
- Most inhabit the **asteroid belt** between Mars & Jupiter.
  - Jupiter's gravity prevented a planet from forming there.




# Origin of the Comets






The nebular theory *predicted* the existence of the Kuiper belt 40 years before it was discovered!

- The leftover icy planetesimals are the present-day **comets**.
- Those which were located between the Jovian planets, if not captured, were gravitationally flung in all directions into the **Oort cloud**.
- Those beyond Neptune's orbit remained in the ecliptic plane in what we call the **Kuiper belt**.

# Exceptions to the Rules

So how does the nebular theory deal with exceptions, i.e. data which do not fit the model's predictions?

**IMPACTS**

- There were many more leftover planetesimals than we see today.
- Most of them collided with the newly-formed planets & moons during the first few $10^8$ years of the Solar System.
- We call this the **heavy bombardment** period.

# Exceptions to the Rules

**Close encounters with and impacts by planetesimals could explain:**

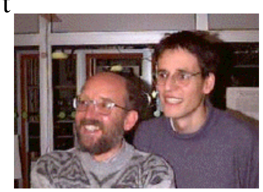
- Why some moons orbit opposite their planet's rotation
  - captured moons (e.g. Triton)
- Why rotation axes of some planets are tilted
  - impacts "knock them over" (extreme example: Uranus)
- Why some planets rotate more quickly than others
  - impacts "spin them up"
- Why Earth is the only terrestrial planet with a large Moon
  - giant impact

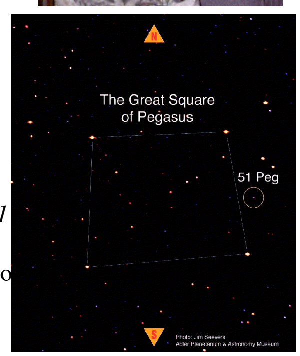
# Lecture 8
# Extrasolar Planets

Reading: Chapter 9

# Extrasolar Planets

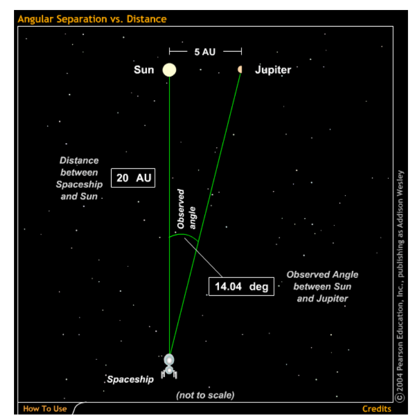
- Since our Sun has a family of planets, shouldn't other stars have them as well?
  - Planets which orbit other stars are called **extrasolar planets**.
- Over the past century, we have assumed that extrasolar planets exist, as evidenced from our science fiction.
  - The Starship *Enterprise* visits many such worlds.
  - But do they exist in fact?
- We finally obtained direct evidence of the existence of an extrasolar planet in the year 1995.
  - A planet was discovered in orbit around the star *51 Pegasi* by Mayor and Queloz at Geneva Obs.
  - Over 100 such extrasolar planets are now known to exist.



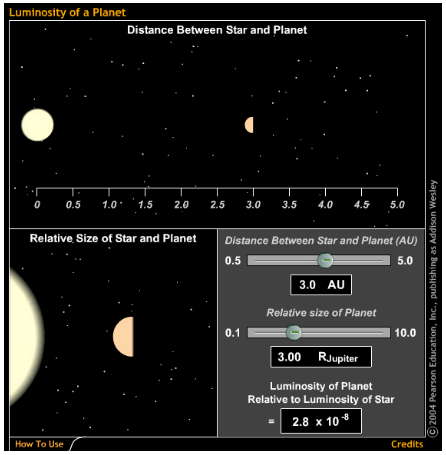



# Detecting Extrasolar Planets: Imaging?

- Can we actually make images of extrasolar planets?
  - NO, this is very difficult to do.
- The distances to the nearest stars are much greater than the distances from a star to its planets.
- The angle between a star and its planets, as seen from Earth, is too small to resolve with our biggest telescopes.



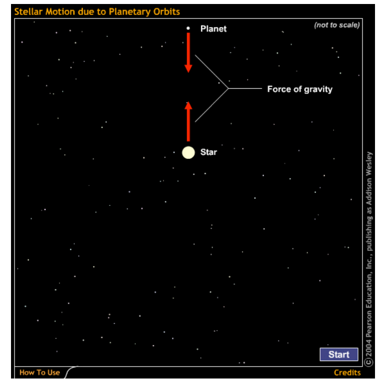
## Detecting Extrasolar Planets: Imaging?

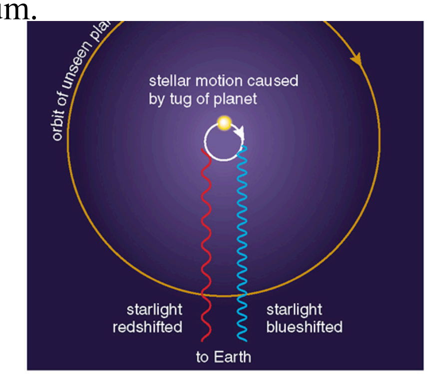



- A star like the Sun would be a billion times brighter than the light reflected off its planets.
- As a matter of contrast, the planet would be lost in the glare of the star.
- Improved techniques of interferometry may solve this problem someday.

## Detecting Extrasolar Planets: *Doppler Effect!*

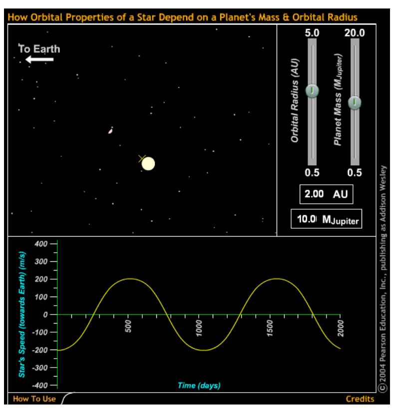
- We detect the planets <u>indirectly</u> by observing the star.
- Planet gravitationally tugs the star, causing it to wobble.
- This periodic wobble is measured from the Doppler Shift of the star's spectrum.

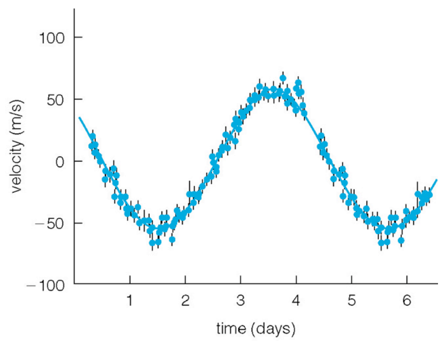





## Measuring the Properties of Extrasolar Planets



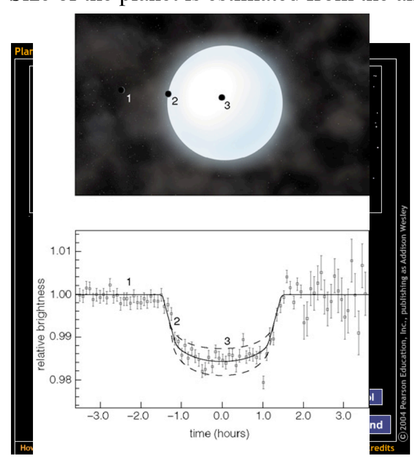






- A plot of the radial velocity shifts forms a wave.
  - Its wavelength tells you the **period** and **size of the planet's <u>orbit</u>**.
  - Its amplitude tells you the **mass of the planet**.

## Measuring the Properties of Extrasolar Planets

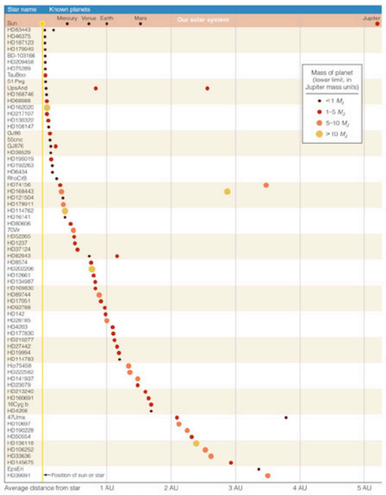
- The Doppler technique yields only planet masses and orbits.
- Planet must eclipse or **transit** the star in order to measure its **radius**.
- Size of the planet is estimated from the amount of starlight it blocks.





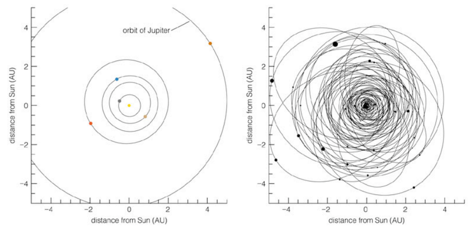

- We must view along the plane of the planet's orbit for a transit to occur.
  - transits are relatively rare
- They allow us to calculate the density of the planet.
  - extrasolar planets we have detected have Jovian-like densities.

## Properties of Other Planetary Systems





- planets appear to be Jovian
- more massive than our system
- Frankly speaking, they are strange!





- planets are close to their stars
- many more highly eccentric orbits than in our Solar System

## Implications for the Nebular Theory

- Extrasolar systems have Jovian planets orbiting close to their stars.
  - Theory predicts Jovian planets form in cold, outer regions.
- Many extrasolar planets have highly eccentric orbits.
  - Theory predicts planets should have nearly circular orbits.
- Is the nebular theory *wrong*?
  - Not necessarily; it may be incomplete.
  - Perhaps planets form far from star and **migrate** towards it.
  - Doppler technique biased towards finding close Jovian planets
  - Are they the exception or the rule?
  - Migrating Jovians could prevent terrestrials from forming
  - Is our Solar Solar System rare?

http://www.utexas.edu/features/archive/2004/planets.html

## Next Stop: Stars!

- Lecture 9: Basic Physics (***Chapter S4***)
- Pick up Homework#2 here!
  - Due next Thursday (September 30)
- Have a good weekend.